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van Egmond, P.; Nijkamp, P.; Vindigni, G.

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# Serie research memoranda

A comparative analysis of the performance of  
urban public transport systems in Europe

Patrick van Egmond  
Peter Nijkamp  
Cabriella Vindigni

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A COMPARATIVE ANALYSIS OF THE PERFORMANCE OF URBAN  
PUBLIC TRANSPORT SYSTEMS IN EUROPE

Patrick van Egmond

TIS.PT

Consultores em Transportes

Inovação e Sistemas, S.A

Lisbon

Peter Nijkamp

Dept. of Spatial Economics

Free University

Amsterdam

Gabriella Vindigni

Dipartimento Scienze

Economico-Agrarie

Universita degli Studi

Catania

Abstract

Regulatory reform in EU transport policy has forced urban public transport authorities to operate increasingly under a market regime. The EU policy favours in particular a system of limited competition through the granting of concessions to public transport operators. This paper seeks to identify the success conditions for local public transport systems in a sample of 22 European cities. On the basis of extensive field research a **systematic** performance table of urban public transport systems in these cities is created with the aim to investigate the impact of four classes of critical success **factors** on the performance of these systems. In the empirical part both a qualitative interpretative analysis and a recently developed tool from **artificial intelligence**, viz. rough set analysis, is deployed in order to derive policy relevant **conclusions**.

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## 1. Setting the Scene

European integration is a fuzzy term comprising a wide variety of socio-political elements, geographical settings and institutional-economic mechanisms. The European Union has originated from an uncoordinated patchwork of different driving forces, missing networks and self-centred regulatory regimes. The **pace** towards more coordinated **policies**, for instance, in the area of a common agricultural policy (CAP) or a common transport policy (CTP), has been long lasting and sometimes frustrating. Nevertheless, Europe is gradually shaping its own political face, a development that urgently **needs** to take place in the light of the foreseen entry of the accession countries (see also Commission of the European Communities 2001).

One of the policy areas in which the European Commission has been active is transportation policy. Policy development in this area is governed by two general principles laid down in the Treaty of Europe, viz. the subsidiarity principle and the proportionality principle. The first principle stipulates: *"In areas, which do not fall within its exclusive competence, the Community shall take action. (...), only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the Member States and can therefore, by reason of the scale or effects of the proposed action, be better achieved by the Community "*, while the second principle has to be interpreted as follows: *"Any action by the Community shall not go beyond what is necessary to achieve the objective of this Treaty "*. Within this overall **framework** a common European policy for the transportation sector is being developed.

One of the foundation stones of the CTP is to introduce more market orientation in the transportation sector in order to increase the efficiency in this rather old-fashioned system. Various mechanisms based on policy devolution are at present envisaged, in particular decentralisation, deregulation and privatisation. Through a strong **adherence** to market **principles** the transport sector is expected to offer an **effective** contribution to an efficiency rise in the European unification process. Such a policy is not only needed for cross-border transportation (e.g., the railway sector, the aviation sector or international freight transport), but also for public transport at various geographical scales ranging from interregional to local transport. The European Commission is at present developing a comprehensive **framework** of appropriate regulations and financial incentives in order to favour the performance of public transport with the help of *market incentives*. From the three possible ideal-typical organization forms of public transport, viz. a public monopoly with closed markets, a system of limited competition and a system of entirely deregulated markets, the Commission supports a **framework** based on *limited competition*.

The present study aims to test whether the gradual transition towards a system of limited competition for urban public transport (or urban mass transit) has been successful in terms of a better achievement of the targets set by the public transport authorities. In addition, the study aims to identify the critical success factors for the achievement of the **success** (or the lack of success) of public

transport systems in various urban regions in Europe based on both a **taxonomic** interpretation and a meta-analytic comparison.

This paper is organized as follows. In Section 2 a concise introduction into European policy on (urban) public transport is offered; particular attention will be given to various policy objectives which serve as a frame of reference for judging the actual achievement of urban public transport systems. Next, we will offer an overview of various organizational forms of urban public transport systems in Section 3. As a step towards a practical policy analysis Section 4 will map out the various critical **success factors** for these achievements. In Section 5 the data base for our **taxonomic** analysis of various European urban public transport systems will be presented. A substantive interpretation of empirical **findings** and results of a more **rigorous** analytical method for handling small sample qualitative data in **comparative** case study research, viz. rough set analysis, based on meta-analytical **principles**, are **contained** in Section 6; the resulting policy **rules** will be interpreted as well. And **finally**, the paper will be concluded with some policy perspectives.

## 2. Basic Elements of European Urban Public Transport Policy

Transport is one of the connecting **principles** of European integration policy (see Nijkamp et al. 1998). This applies to **all** geographical levels ranging from international to local. For example, at the international level, the policy on Trans European Networks (TENs) is of **utmost importance**. At the local level, the EU **competence** regarding the operation of local networks is limited by the **above-mentioned principles** of proportionality and subsidiarity, but the general **objective** of favouring efficiency in European transport systems applies here as well, beside the **fulfilment** of socio-economic objectives (**such** as employment generation) and environmental objectives (e.g., reduction in CO<sub>2</sub> emissions in the transport sector).

Urban transport is generally seen as a public service of great **importance**. At the individual level it is a service that **meets** the **needs** of mobile citizens, while at a societal level it **contributes** to quality of life and sustainability. The EU directorate-general on Transport has even positioned public transport as a **crucial** service for European citizens (see DG Transport 1996), witness the following statements: *“Needs of citizens are put at the **centre** of decisions about transport provisions”, and: “Ideally, public transport **should** be **accessible, affordable** and available to **all** citizens. Financial and technical considerations **may** constrain this, but the Commission believes that the goal is important and worth of debate...”*. The Commission’s policy, therefore, is **focussed** on a **higher** use intensity of public transport.

Clearly, a major weak element in the provision of high quality urban and suburban public transport is the low transparency in the organization of European public transport. The organizational models range from public enterprises (with a dominant role of public authorities in ownership, planning and operation) to private enterprises in deregulated **markets**. Public monopolies have become notoriously inefficiently operating **firms** due to **lack** of incentives in a protected market. Privately

organized firms in the public transport market are assumed to operate much more efficiently, but this efficiency rise may be offset by a loss in terms of integration of public transport systems (see also Van Ooststroom 1998). Consequently, the European Commission has formulated a blend of these two extreme forms that might offer a better compliance with the needs of both citizens and society at large. This organizational mix presupposes a light regulation, which may favour the achievement of production efficiency, cost efficiency, socio-economic objectives and client orientation.

The semi-market model advocated by the Commission is based on a system of concessions to be granted on a competitive basis by responsible public authorities to various public transport operators. The regulatory and operational framework of the services to be offered has to be specified by the public authority. This model has two major consequences. First, it leads to a shift in the mission of a public transport operator from a duty to deliver a service toward the establishment of a contract between two parties, viz. the public authority and the operator, so that the two roles cannot coincide anymore. Clearly, in the accompanying legal framework the rights and duties of both parties (e.g., geographical coverage of the transport service, frequency and tariff structure) have to be specified. In the second place, the concession model introduces clearly market incentives, as a concession has only a limited time span and a new concession is subject to a call for tender. The new regulatory framework of the EU in the area of public transport comprises the following general objectives (see DG Transport 1996):

- to encourage increases in use of public transport;
- to encourage system integration and fulfilment of public service requirements;
- to establish incentives for service providers and planning authorities to improve accessibility, efficiency, quality and user friendliness of public transport systems;
- to promote financial conditions required for making public transport services more attractive, both for public and private investors;
- to ensure minimum requirements in respect of the qualifications of staff, thus guaranteeing high levels of reliability, safety and security;
- to safeguard flexibility in relation to specific national, regional and local priorities and the particularities of national legal systems.

These objectives would stimulate a strong public transport sector in Europe and eliminate existing barriers that induce inefficiencies. The operationalisation of the above principles at a local scale is mainly a responsibility of public authorities at a local or regional level.

Another possible government intervention in the public transport sector may be based on the provision of subsidies or loans, from either the European Regional Development Fund (ERDF) or the Cohesion Fund (CF). Financial means from the ERDF can be obtained in order to stimulate small- and medium-size enterprise activities, to favour generally productive investments, to improve weak infrastructures or to encourage local development. Support from the CF serves to favour socio-

economic integration in Europe, *inter alia* for the improvement of accessibility or connectivity to the TENs.

3. The Organization of Local Public Transport Systems

Local public transport (LPT) systems – in EU countries and world-wide – exhibit an enormous variety of appearances in terms of organization and relationships with stakeholders, as well as of planning and control systems. In the framework of our study we will deploy a practical classification of LPT systems on the basis of the ‘*right of initiative*’, where the fundamental and legal decision on how to organize an LPT system rests either with a public authority or with the market. In the first case, the transport authority has a formal monopoly, whereas in the second case LPT initiatives originate from the – often anonymous – free market system (though restricted by legislation and regulatory measures). Figure 1 offers a systematic further distinction of the possible organizational structures of the above major classification.

The LPT system is usually operating in a complex force field with several key players. In our taxonomic approach we make the following distinction:

- consumers/users (C)
- local voters (K)
- local authorities (A)
- public transport firms or operators (O)

This list of stakeholders can be used as the basis for an integrated typology of the two above-mentioned initiatives in relation to entry conditions to the LPT market.

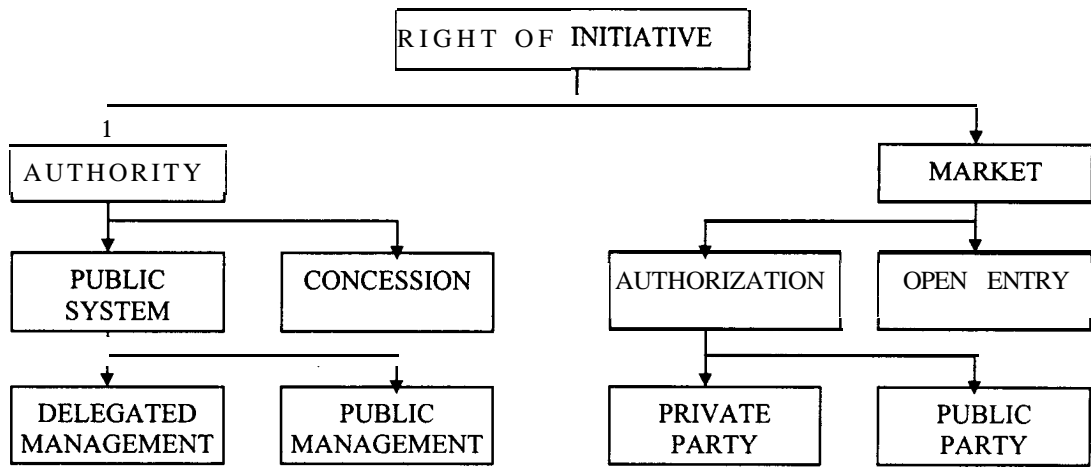


Figure 1. Taxonomy of LPT initiatives

The parties involved with LPT systems (i.e., A, C, K, O) execute different roles and functions on the market for collective passenger transport. In particular, the following activities and tasks can be distinguished:

- supply (delivery) of LPT services to clients (D)

- payment for LPT service provision (P)
- **democratic** (voting) impact on quality and quantity of LPT services or systems (V)
- public regulation of supply **and/or** demand of LPT services (R).

The execution of these tasks and **roles** brings the four above-mentioned parties together, as these items make up the linking pins between the parties concerned. The linkage structure between these four classes of stakeholders **can** now schematically be mapped out using a connectivity matrix (see Figure 2).

Linkage to from	A	C	K	O
A				
C				
K				
O				

Figure 2. A connectivity matrix between the four stakeholders in LPT systems

The **nature** of the linkage between A, C, K and O in a given LPT constellation **can** be denoted by filling the entries of the matrix with the corresponding relevant items D, P, V or R. In this way, a **systematic** way of depicting (**almost**) **all** relevant LPT constellations is achieved. Of course, there are **many** organizational forms of stylised linkage patterns. By way of illustration we **will** present here one arbitrary possible LPT constellation, namely one based on a LPT initiative from the market accompanied by a system of public authorisation. The corresponding connectivity matrix is in this case the following (see Figure 3).

Linkage to from	A	C	K	O
A		R		R
C				P
K	V			
O		D		

Figure 3. Connectivity **structure** of a **market-based** LPT constellation governed by a system of public authorisation



In an ideal-typical form this constellation **can also** be represented as follows (see Figure 4).

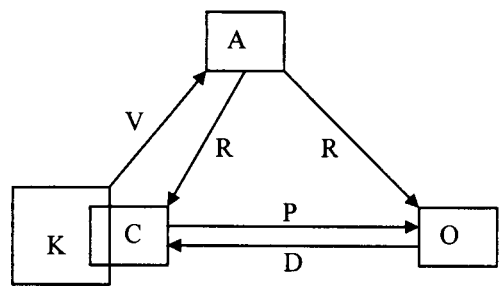


Figure 4. Illustrative organization of an LPT market system under a regime of a public authority

Needless to say, there are numerous types of LPT constellations that **can** be depicted by the connectivity matrix in Figure 2 (see for a review **also** Van Egmond 2001). Systems of public monopoly, subsidised LPT systems, **competitive** tender procedures, **selective** concessions, delegated management, or public ownership **can all** systematically be handled in this way. This approach **can** be extended by including as driving forces, besides external environmental factors, **also** different levels of planning **competence** in LPT systems, notably **strategic**, tactical and operational planning. This **will** be **further discussed** in the next section.

**4. Success Factors of LPT Systems**

To increase the use and efficiency in LPT systems it is necessary to gain more insight into the driving forces or determinants of the performance of **such** systems. Base on the various EU **directives** referred to above, a subdivision **may** be made into two classes of **objectives**. First, there are **socio-economic** performance criteria, in particular, the increase in the use of LPT systems, an improvement in environmental quality conditions or a contribution to employment. In this framework, one **may also** mention accessibility, quality, availability and affordability of LPT services. In the **second place**, there are **financial-economic** performance criteria, in particular internal cost-efficiency and **customer-oriented** effectiveness. This complex set of interlinked objectives/criteria for the functioning of LPT systems is depicted in Figure 5. Clearly, the actual fulfilment of **such** policy goals would have to be ‘explained’ from a set of **generic** and **site-specific** background factors. The **main** indicator for policy success is the **usage** of local mass transit systems, which is a **composite** indicator of **many** underlying policy-relevant criteria as described in Figure 5.

The performance of LPT systems is thus critically contingent **upon** a set of major driving forces (critical **success** conditions, abbreviated as **CSCs**). These are:

- ❑ external factors
- ❑ **strategic** factors
- ❑ tactical factors
- 0 operational factors.

We will concisely describe these 4 CSCs.

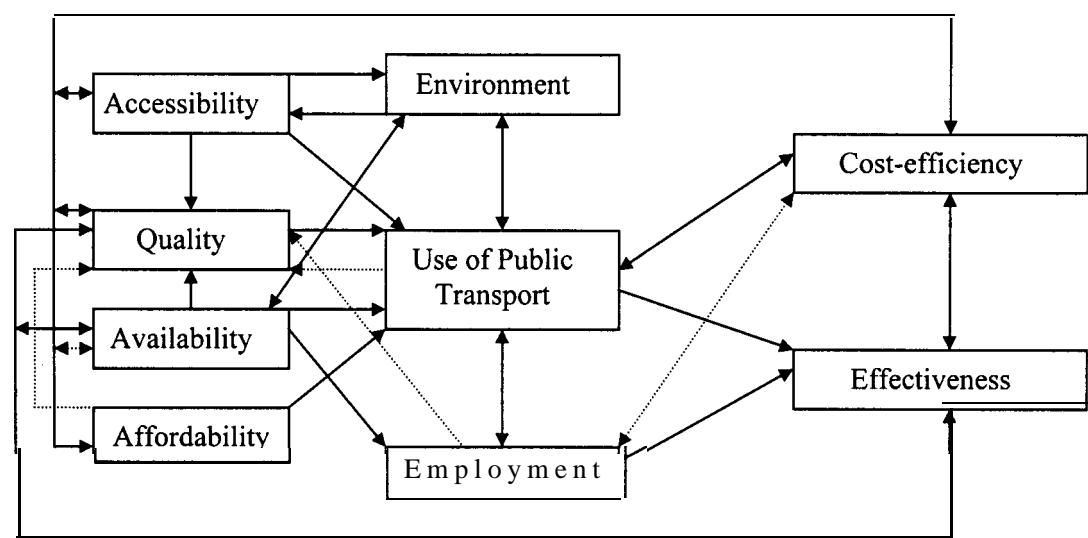


Figure 5. Interaction scheme of LPT objectives/criteria

A. *External CSCs*

These factors cannot be controlled by the LPT agency concerned. We will distinguish here 3 major external CSCs:

- A1. *population*. This factor refers to the potential demand for LPT services and represents also an efficiency indicator in relation to the critical mass of LPT users (including also the population from adjacent areas as well as tourists).
- A2. *population density*. This factor is a proxy for the economies of geographical density and influences the type of LPT systems offered.
- A3. *population distribution*. This factor refers in particular to the degree of uniformity or heterogeneity in the geographical dispersion of people (e.g., a poly-nuclear structure versus an urban-rural dichotomy).
- A4. *incidental large urban manifestations*. Large urban manifestations such as exhibitions, sports events or cultural events exert a significant but ad hoc impact on the performance of LPT systems.

B. *Strategic CSCs*

The goals of LPT systems are also influenced by strategic factors determined by the various stakeholders, in particular national, regional and local authorities. The strategic factors distinguished here are:

- B 1. *political interest*. In both publicly organized and market-oriented LPT systems public authorities have a significant impact on the functioning of LPT systems through both regulating and facilitating interventions.

- B2. *specific LPT regulations*. Within the EU context of subsidiarity and proportionality many initiatives have been developed which aim to improve the efficiency in the LPT sector. Regulatory uncertainty **may** have a negative impact on the LPT performance.
- B3. *integrated LPT and urban development*. Urban and suburban development plans need to be supported by **sufficient** availability of LPT systems. Such an integration **needs** to be realized on both a structural and a project basis in order to attract **sufficient demand**.
- B4. *coordination between LPT sector and public authorities*. In this framework various tasks play a role, **such as** granting concessions, evaluation of licences by a responsible public authority, provision of subsidies etc.

### C. Tactical CSCs

The tactical level addresses the question how general objectives can be converted into an actual implementation of LPT services. The following categories can be distinguished:

- C1. *organizational framework*. The organizational constellation refers in particular to the right of initiative as spelt out in Figure 1.
- C2. *financial framework*. The financial ramification is concerned with financial aspects of various LPT tasks including the contractual aspects (e.g., management contract, gross cost contract, net cost contract).
- C3. *subsidies*. These forms of **financial** support comprise both structural and non-structural subsidies. The **latter** category concerns financial assistance for ad hoc projects. Structural subsidies **can** be subdivided into direct and indirect subsidies. Direct subsidies **mean** a transfer to the LPT operator, while indirect subsidies **mean** a financial support via the user. Also cross-subsidisation between various public services or LPT services is possible.
- C4. *private-public partnership*. This type of **co-operation** between the public sector and the private sector **may relate** to both the operational execution of LPT services and the operation of LPT infrastructure projects. The motives for this **co-operative** mode are **inter alia**: benefits from synergy, multifunctional development, blend of regulatory and business culture, better coverage of market risks etc.
- C5. *symbiosis between LPT and other transport modes*. A better integration **may generate** win-win situations, e.g., in case of multi-modal passenger terminals.

### D. Operational CSCs

At the operational level we address the actual supply and execution of LPT services, in particular production and sales activities. The following factors can be distinguished here:

- D1. *variety in supply of LPT services*. Relevant **categories** are **inter alia**: bus, tram, metro, train, people mover etc.

- D2. *privileged position of LPT compared to other traffic*. Priority rules for LPT may offer this system a more competitive position.
- D3. *density of LPT*. Density may refer to both the service (e.g., frequency and intensity) and the infrastructure.
- D4. *integration of LPT*. The various LPT systems may have a higher degree of cohesion through the integration of fares, logistics, routing etc.
- D5. *LPT marketing and information*. This factor refers to the need for market and client orientation of a modern LPT sector.

These CSCs will now be used as a test framework for a comparative analysis of LPT systems in various European cities.

### 5. Creation of the Data Base on LPT Systems in European Cities

The classification of the CSCs discussed in the previous section needs a further operationalisation by indicating to which extent the various LPT objectives and CSCs are realised in each of the European cities investigated in our study. The European case cities selected in our study cover a wide range of urban size categories and of organizational/regulatory frameworks and offer a representative cross-section of different urban public transport constellations. This will allow a comparison of both urban regions of similar sizes but functioning under different arrangements and of urban regions of various sizes but functioning under similar arrangements (cf. also Yin 1994). The following cities were ultimately chosen (see Table 1).

1. Athens	9. Dresden	17.Mannheim/Heidelberg/ Ludwigshafen
2. Barcelona	10. Dublin	18. Oslo
3. Berlin	11. Hagelanden	19. Paris
4. Bern	12. Hanover	20. Rome
5. Bordeaux	13. London	21. Stockholm
6. Brussels	14. Leeds	22. Vienna
7. Budapest	15. Lisbon	
8. Copenhagen	16.Malmö/Lund/ Helsingborg	

Table 1. List of selected European case cities

For each city in this list the set of performance (success) indicators included in Figure 5 has been assessed in a qualitative (categorical) form by using local expert information (see for details Van Egmond 2001). These scores are based on the degree of fulfilment of objectives included in Figure 5. The central objective is usage of urban mass transit systems, as a result of the various background

factors included in this **figure**. An expert summation of **all** these individual performance criteria **may** then lead to a comprehensive score for the LPT success according to the following trichotomic classification of the performance of a given LPT system in **any** of these cities: successful (score 1); moderately **successful** (score 2); unsuccessful (score 3); unknown success **receives** a code 4. The actual performance assessments based on reports, articles, yearbooks, research, internet and casual interviews **can** be found in the **first** row (P) of Table 3.

To map out in a **categorical** form the CSCs for **each** city a **codified** qualitative information table has to be deployed (see Table 2.). Next, empirical estimates of **all** 18 factors determining the CSCs have been made for **all** 22 European case cities, again based on various local information sources on LPT. With the help of extensive **comparative fieldwork** the codification included in Table 2 has been assessed for **each** individual city. The empirically estimated information is **contained** in Table 3 under the headings A through D. The information in the **latter** table **will** now be treated in two steps. First, we **will** offer a qualitative interpretation of the results, based on an analysis of **frequencies** of CSCs in this matrix. Next, we **will** deploy a new multivariate classification method for nominal measurement scales, coined rough set analysis.

**6. Empirical Results**

A qualitative **inspection** of the **coded** data matrix (Table 3) offers **already quite** some interesting insights. The performance scores in Table 3 demonstrate that from our sample of 22 European cities at least 5 cities are regarded as **having** an unsuccessful operation of their LPT systems. A moderate success is **claimed** by 9 cities, while a good performance **can** apparently be found in 7 cities. For one city the performance of its LPT systems could not be unambiguously **defined**. So the general **finding** is that the present conditions of a European policy of limited competition has led to **rather** successful outcomes, since a total of 16 cities **out** of 22 cases has moderately to high **successful** LPT systems (measured in terms of an increase in the use of LPT).

From the set of 22 cities a total of 16 **may** be considered as cases of limited competition, the dominant organizational form of EU LPT systems. From these 16 cases, a total of 10 **may** be interpreted as based on initiative by the public authority, while the remaining **ones** represent an initiative by the market (or an ambiguous case). In **general**, these cases appear to yield **rather** promising results. Thus, one **may** conclude that the adoption of a **specific** organizational-institutional form of LPT based on limited competition **provides** the conditions for a balance between the socio-political **objectives** of sound socio-economie and **financial-economic** development of LPT systems.

If we make a distinction into external, **strategic**, tactical and operational background conditions for the performance of LPT systems, then we arrive at the following general conclusion on their impact on the LPT performance.

		Codification of CSCs					
		1	2	3	4	5	6
<b>CSCs</b>	<b>External</b>						
A1	Size	>3 mln	3 mln>x>1 mln	1mln>x>500.000	<500.000		
A2	Nr. of people/km2	>2000	2000>x>1000	<1000			
A3	Distribution	Yes	Not significant				
A4	Incidental large manifestations	Yes	No				
	<b>Strategic</b>						
B1	Policy interest	Large	Average	Not significant			
B2	Specific LPT legislation	General legislation	Specific legislation	Not significant	Unknown		
B3	Integration LPT and urban development	Systematic	Project - based	Not significant			
B4	Match between LPT and authorities	Yes	No				
	<b>Tactical</b>						
C1	Organizational framework	Regulated	Limited competition; initiative of authorities	Limited competition; initiative of market	Limited competition; initiative of market/ authorities	Deregulated market	Combination of main types
C2	Financial framework	Net cost contract	Gross cost contract	Management contract	Unknown		
C3	Subsidies (% operational costs)	<25%	25%-50%	>50%	Unknown		
C4	Public-private partnership	Infrastructure related	LPT service related	Infrastructure and LPT service related	No partnership	Unknown	
C5	Integration of LPT with alternative modes of transport	Yes	Not significant	Unknown			
	<b>Operational</b>						
D1	Variety in LPT services	Bus/tram/ (sub-)urban heavy rail	Bus/metro/ (sub-) urban heavy rail	Bus/(sub-) urban light rail/ (sub)-urban heavy rail	Bus/(sub-) urban heavy rail	Bus/tram and/or metro and/or light rail/ /(sub-) urban heavy rail	Other important combinations
D2	Priorities of LPT with respect to other traffic	Yes	No	Unknown			
D3	Density of LPT	High	Average	Low	Unknown		
D4	Integration of LPT	High	Average	Low	Unknown		
D5	LPT marketing and information	High	Average	Low	Unknown		

Table 2. The codified table for the CSCs of LPT systems

	EUROPEAN CASE CITIES																					
CSCs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
P	3	2	2	1	3	2	2		12	13		2		14	1	2	3	2	12		2	1
Al	1	1	1	4	3	2	2	2	3	2	3	3		12	3	2	3	2	12		2	2
A2	2		1	3	3	1	1	1	2	2		111		2	2	3	2	2	2		13	1
A3	12	12	2	2	1	2	2	2	2	2	1	1	2	2	1	1	1	2	2	2	2	2
A4	2	2		12	2	2		11	2		12	12	2		12	11		2		2		11
B1	2	1	1	1	3	2		2	12		2	1111	2		2	2	1	1	1	1	1	1
B2	2	2		12	11	4		2	12		11		2	12		2	12	2		1	2	3
B3	2	1	1	1	2	12		12	2		12		2	12		2	2	11		2		13
B4	2		12		12		12		11		12		11	12		12	11		1	1		2
C1	12	2	11		3	2	2	2	3	3		2	2	6	6	2	2	2	4	12	3	
c2	12	2	3	3	11	2	2	3	2		2	2	12		12	12		2	2		2	
c3	2	2	3	2	3	3	3	2	3	1	3	2	4	4	2	3	2	2	3	3	3	3
c4	11	3	4	4		13	4	4	4	5	3	4	3	4	5	4	4	4	4	12	4	
c5	13	11		2	11	2	2		2	3		3	1	2	3	2	1	1	1	1	1	1
D1	2	5	5	5	4	5	5	4	14	13		5	4	5	4	5	5	5	5	5	5	5
D2	12	13		13	2	3	3	3	3	3		3	2	13		12		3	11		3	
D3	2	2	12		3	2	2		11	2	2		12	4	2	14		11	2		2	2
D4	3	11		2		3	1111	2		12		2	3	3	2	1	1	1	2	1	1	
D5	2	12	3		3	4	3	2		12	4		13	2	3	2	4	14	14		2	

Table 3. The coded data base on performance (P) and CSCs (A, B, C, D) of European LPT systems

The *external* factors do not appear to exert an unambiguous impact on the success scores of LPT. Although these are some clear links with some of the constituents of the external factors, the overall result is inconclusive.

For the *strategic* factors we observe a more straightforward influence on the success score of LPT. In particular, the quality of governance and management appears to be a decisive positive factor (e.g., for Bern and Paris). On the other hand, overorganization of the LPT Systems leads most likely to a failure.

At the *tactical* level we also observe interesting findings. In particular, cities with an LPT system governed by regulated or limited competition appear to yield a good performance. This should also be reflected in a sound division of financial responsibilities of all stakeholders, especially in the context of a gross cost contract or a clear management contract. Furthermore, it appears that high subsidies for LPT systems lead to an unsatisfactory financial and socio-economic performance, while moderate subsidies appear to yield in general good results. Clearly, marked incentives do stimulate the performance of LPT systems.

And finally, at the *operational* level we find that the presence of an integrated LPT system with different modalities tend to offer a better performance.

We may conclude that there is not a single, preponderant and unambiguous performance cause for LPT systems. Our cases demonstrate clearly that the success (or failure) has a multidimensional causality structure. This means that we have to investigate also the simultaneous occurrence of combinations of the four above mentioned critical success conditions. This will be done in the next stage of our analysis.

In the second place, we will now use a recently developed qualitative classification method, viz. *rough set analysis*, to extract new insights from the nominal data in Table 3. We have a data base of 22 cases (i.e., cities) each characterised by a performance indicator (or nominal value of a success indicator). Furthermore, the discriminatory score of this performance indicator is 'explained' by the nominal values of the CSCs in our codified table, subdivided into four main categories (external, strategic, tactical and operational). Each of these categories is subdivided into subcategories, so that altogether we have 18 explanatory factors. Thus, we have to explain the nominal expression for a success factor regarding the performance of LPT systems from an underlying set of nominal expressions for CSCs. It is clear that, even apart from the small sample of 22 cities, this is statistically an impossible task due to the low level of measurement (i.e., nominal data).

Nevertheless, our codified information table may represent a latent structure through which the value of a performance indicator may yet be explained by means of combinatorial logic. In this context, the use of techniques from artificial intelligence, in particular rough set analysis, may be helpful. Rough set methods are multivariate classification methods that aim to detect patterns in a data base, even in the case of low measurement scales (including nominal scales). They are not based on



conventional statistics, but on the identification of deterministic rules (or statements) that are supported by the data base at hand.

Such rules often take the form of 'if...then' statements and reveal under which conditions (i.e., combinations of values of the explanatory variables in the data base) a certain score on the dependent variable is valid. Thus, the result of a rough set analysis is a series of deterministic statements ('decision rules') of an 'if.. . then' nature. If a certain variable shows up in all conditional statements, it offers apparently an explanatory contribution in all cases. Such a variable is called a 'core'. In this deterministic way relevant critical success factors can be identified.

We will now present the conditional statements which emerge from the application of a rough set analysis to the above data base (using the ROSE software programme). This application of rough set methods leads to the following 7 decision rules, i.e. conditional statements which explain under which conditions (values of CSCs) a certain performance score is realized.

- (i).  $(B2 = 2) \& (C4 = 4) \& (C5 = 3) \rightarrow P = 1$
- (ii).  $(C4 = 4) \& (D3 = 2) \rightarrow P = 1$
- (iii).  $(A3 = 2) \& (C1 = 2) \& (D1 = 5) \& (D4 = 1) \rightarrow P = 2$
- (iv).  $(D5 = 1) \rightarrow P = 2$
- (v).  $(A1 = 2) \& (B1 = 2) \& (C2 = 1) \rightarrow P = 2$
- (vi).  $(A3 = 1) \& (B2 = 1) \& (C5 = 2) \rightarrow P = 3$
- (vii).  $(C2 = 1) \& (D4 = 3) \rightarrow P = 3$

These results show that there is no core (i.e., a common factor in each of these decision rules), although the accuracy of the approximation in this set of rules appears to be high. Essentially there are many reducts that provide an optimal representation of this multivariate classification. Attributes with a relatively high frequency in these reducts appear to be A2, A3, B2, B4, C1, D3 and D5, with the highest frequency for D5.

The various decision rules specified above can be interpreted in a straightforward way. Let us take as an example rule (vii), which states that a failure of a LPT system (i.e.,  $P = 3$ ) may be the result of a combination of a financial framework based on a net cost contract (i.e.,  $C2 = 1$ ) and a very low level of integration within the LPT system concerned (i.e.,  $D4 = 3$ ).

These decision rules look rather complex, but can in various cases be interpreted in a straightforward way. For example, rule (i) claims that a successful LPT system may emerge when there is a specific, customized and non-overloaded regulatory regime and when the privileged position of LPT systems is so strong, that no public-private partnership is necessary. Similarly, rule (ii) stipulates that, with a fair density of LPT systems, such that no complementary support mechanisms in the form of public-private partnership are needed, the LPT system concerned tends to be successful. Another

example concerns rule (iv) which states that a medium success of LPT systems may already be expected with an intensive effort regarding marketing and information. An example of a failing performance can be found in rule (vii) which claims that a combination of a financial constellation based on a net cost contract and a low integration level of LPT systems tends to lead to a low success.

## 7. Concluding Remarks

The necessary rise in efficiency and service provision in LPT systems requires a drastic reform in the organisation of urban mass transit systems. Such a regulatory transformation needs a closer orientation towards market principles in which delivery of high quality service to paying customers forms a crucial objective. This regulatory reform should also respect the peculiarities of LPT systems, such as its public nature, the indivisibility of parts of the infrastructure and the high fixed costs. Consequently, a shift towards mainly limited forms of competition seems to be plausible.

In our study, the success conditions for LPT systems in 22 European cities have been investigated. It turns out that these critical success factors can be subdivided into four categories, viz. external, strategic, tactical and operational. From these classes of conditions, in particular the strategic, tactical and operational factors appear to exert a major influence.

In general, the regulatory reform of public transport has created new challenges and also new opportunities for a more successful functioning of these systems. Our comparative analysis has demonstrated that in the past years – despite variation – many European cities have managed to organize their LPT systems in a more efficient and satisfactory way.

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